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POTATO GROWING IN IOWA AS AFFECTED BY TEMPERATURE

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AMES, IOWA

SUMMARY

The white potato is distinctively a cool-season crop. On the average the best yields are secured by planting early in order to get the crop as far along as possible in advance of the high summer temperatures.

The heaviest yields, on the average, were secured from the plantings made shortly after the seasonal rise in temperature crosses the 40° line.

For central Iowa, this period is usually reached during the first half of April.

In a date-of-planting-in-relation-to-yield experiment with late potatoes, covering six years, the results were as follows:

The average of the April plantings was 124.4 bushels per acre and for the June plantings, 76.2 bushels.

The planting dates covered by the last week of April and the first two weeks in May averaged about the same.

The plantings made after the middle of May gave a successive decline in yield.

Between the first and last planting there was a spread of 65.8 bushels per acre.

The minimum vegetative temperature for corn is fully ten degrees above that for potatoes. The general practice of planting late potatoes after corn planting is contrary to the temperature requirements of the two crops, and is regarded as one of the important reasons for the decline in potato yields in Iowa.

In general, the early market is the most profitable. Early planting and early marketing go hand in hand.

The danger from frost injury at harvest time may be largely eliminated by early planting.

POTATO GROWING IN IOWA AS AFFECTED BY TEMPERATURE

By A. T. Erwin and R. A. Rudnick.

Early planting of potatoes in Iowa will give the best average yields. This was shown in a six-year experiment carried on by the Iowa Agricultural Experiment Station at Ames, to determine how potato growing is affected by various temperature conditions. The heaviest yields on the average followed when the crop was planted shortly after the seasonal temperature reached 40° and above. In central Iowa this period is usually reached in the first half of April.

Because the potato is distinctively a cool-season crop, high summer temperatures limit potato production in the cornbelt. This is particularly true with regard to the period of tuber development. The problem of determining a time of planting which, on the average, is most likely to give the plant the most favorable climatic conditions during the period of tuber formation, particularly from the standpoint of temperature, is an important one.

This bulletin presents the results of a study of the relation of temperature to potato production in Iowa. As with all experiments of this character conducted under field conditions, it is impossible to eliminate entirely other climatic factors which may have a bearing, particularly rainfall. In the experiments here reported, the work was so planned as to make the temperature factor the dominant one.

It was not the thought to establish certain arbitrary dates of planting, but rather to learn to what extent the grower may plan his crop schedule, from the standpoint of prevailing average temperature conditions during the growing season in his locality, so that he may secure maximum returns on his potato crop.

YIELD IN RELATION TO TIME OF PLANTING.

This phase of the investigation involved a series of plantings made at ten-day intervals. These successive plantings followed the seasonal rise in temperature. The area of the plots was one-fifth of an acre each. The Rural New Yorker was used thruout the experiment, because it is the leading main-season variety grown in Iowa, and one which is outstanding for its heat-enduring qualities. The dates of planting ranged from approximately the first week in April to the second week in June, in the years 1910 to 1916, inclusive. The range

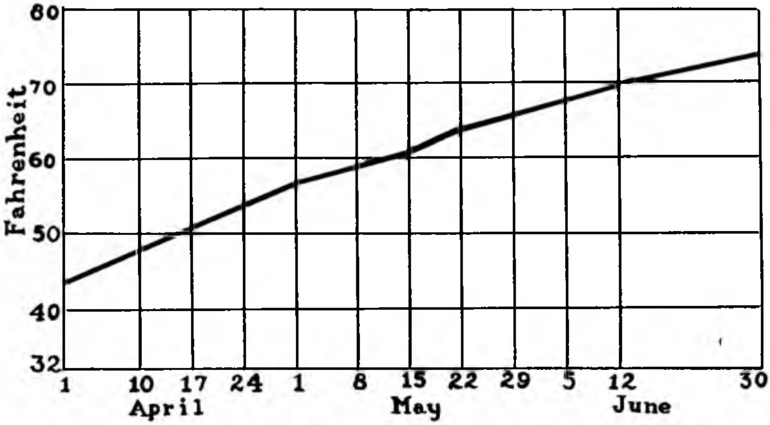

Fig. 1. Graph showing normal range of temperature and dates of planting covered in the experiment.

of the normal mean temperature and the dates of planting covered by the experiment are indicated in the graph in fig. 1.

A summary of the annual crop yields for the experiments for a period of six years at Ames is shown in table I and in the graph, fig. 1. Because the grading of table stock is more generally practiced than ever before, the net yield of marketable tubers is given along with the total yield. The complete data in detail are given in table II.

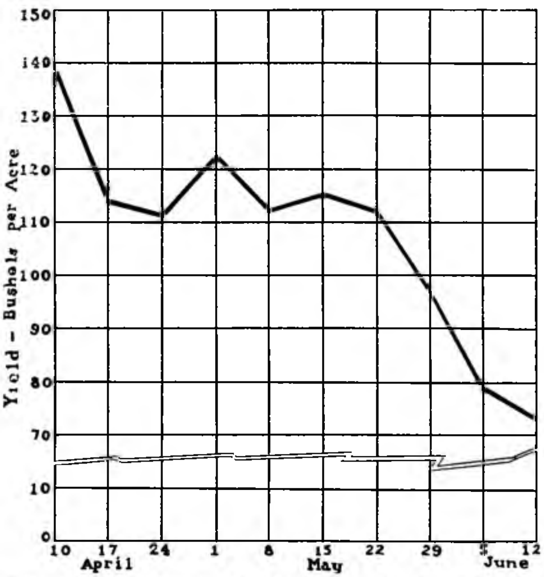

Fig. 2. Average yield from successive dates of planting for the years 1910-11-12-13-14-15 and 16

The data in table II, both as to gross yields and net yields of marketable stock, indicate that on the average the earliest planting is most profitable at Ames. Between the first and last plantings there is a spread of 65.8 bushels per

TABLE I. SUMMARY OF POTATO YIELDS FOR DIFFERENT DATES OF PLANTING OVER A PERIOD OF SIX YEARS, 1910 TO 1916.

Date of Planting	Total yield bushels per acre	Marketable yield per acre*	Culls, bushels per acre
April 10	138.7	119.5	19.2
April 17	114.1	92.2	21.9
April 24	112.4	95.5	16.91
May 1	123.07	105.51	17.56
May 8	111.95	94.71	17.24
May 15	114.63	100.19	14.43
May 22	112.43	98.66	13.79
May 29	96.61	83.85	12.76
June 5	79.46	63.84	12.62
June 12	72.89	60.06	12.81

*A 1¾ inch round mesh screen was used in determining the proportion of marketable or number one stock.

acre, and an average gain of 15.6 bushels per acre in favor of the earliest planting. The May 1 planting shows a gain over the two preceding dates of planting.

This gain, however, is more apparent than real. In two of the years, 1912 and 1915, the May 1 planting shows a gain which was sufficiently pronounced to affect the average for the entire six-year period. In fact, there are individual years in which other dates of planting show exceptional yields which are out of line with the general trend for the six-year period. In 1912 the May 15 planting, for example, for that particular year was the best of all. The irregularities of the season probably account for this. Field experimental data are to be interpreted in the light of the general trend of the entire period.

For the May 1 planting, the percentage of culls was greater than for other periods. On the whole, the data seem to suggest that if the planting is not done early, then about May 1 is likely to prove a favorable time. The average yield for all of the May 1 plantings was 123.1 bushels. In three of the years, however, 1920, 1912 and 1915, the yields were 131.4, 135.5 and 143.3, respectively, or an average of 13.6 bushels in excess of the normal for the six-year period.

The heaviest yield of all the May 1 plantings was that of 1915, which was 14 percent above the average for this date of planting. The temperature factor is significant in this connection. The season of 1915 was one of subnormal temperature. The May deficiency was 4.3°; June, 1.3°; July, 4.4°; and August, 5.6°; or an average monthly deficiency of approximately 4° for the above months. The accumulated deficiency for the growing season was 173° F. A subnormal temperature, particularly for the months of July and August, was accompanied by unusually good yields of potatoes for this locality, a result which indicates that the cool temperature for the growing season was the dominant factor favorable to potato production.

TABLE II. POTATO YIELDS BY YEARS, FOR DIFFERENT DATES OF PLANTING —1910-16.
Yields are given in bushels per acre.

Date of Planting	1910*				1911			
	Total Yield	Mar-ket-able	Culls	Per-cent Culls	Total Yield	Mar-ket-able	Culls	Per-cent Culls
April 10	--------	--------	--------	--------	54.67	46.17	8.5	15.55
April 17	--------	--------	--------	--------	63.87	54.08	9.79	15.33
April 24	--------	--------	--------	--------	96.58	84.6	11.97	12.39
May 1	131.4	119.1	12.35	9.4	91.89	83.35	8.53	9.28
May 8	120.9	110.2	10.75	8.89	98.97	88.46	110.51	10.62
May 15	115.3	94.5	10.8	10.26	104.95	92.85	12.1	11.53
May 22	110.5	102.5	8.05	7.29	109.18	95.88	13.37	12.25
May 29	75.82	70.87	4.95	6.40	78.6	70.61	7.98	10.15
June 5	54.4	49.8	4.6	8.46	77.8	70.01	7.79	10.01
June 12	81.6	74.8	6.76	8.28	65.79	60.32	5.47	8.31

Date of Planting	1912†				1914			
	Total Yield	Mar-ket-able	Culls	Per-cent Culls	Total Yield	Mar-ket-able	Culls	Per-cent Culls
April 10	--------	--------	--------	--------	139.8	124.4	15.4	11.2
April 17	--------	--------	--------	--------	138.8	119.4	19.4	13.98
April 24	105.5	99.4	6.1	5.78	124.7	109.4	15.3	12.27
May 1	135.5	127.7	7.8	5.76	112.3	93.6	18.7	16.65
May 8	96.3	96.9	4.4	4.57	98.9	78.9	20.	20.22
May 15	160.4	154.1	6.3	3.93	114.2	98.	16.2	14.19
May 22	155.4	148.7	6.7	4.31	70.4	53.3	17.1	24.29
May 29	135.6	126.9	8.7	6.42	65.2	53.3	11.9	18.25
June 5	67.1	62.8	4.3	6.41	66.2	48.8	17.8	26.73
June 12	53.8	48.9	4.9	9.11	89.3	65.6	23.7	26.54

Date of Planting	1915				1916			
	Total Yield	Mar-ket-able	Culls	Per-cent Culls	Total Yield	Mar-ket-able	Culls	Per-cent Culls
April 10	216.8	203.05	13.75	6.36	143.7	104.5	39.2	27.28
April 17	148.8	132.8	16.	10.75	148.8	62.7	42.3	28.43
April 24	107.5	93.6	13.9	12.93	127.9	90.6	37.3	29.16
May 1	143.3	126.55	16.75	11.69	124.	82.75	41.25	33.27
May 8	131.1	113.	18.1	13.81	125.5	85.8	39.7	31.63
May 15	76.3	68.5	7.8	10.22	126.6	93.2	33.4	26.38
May 22	110.	97.8	12.2	11.09	119.1	93.8	25.3	21.24
May 29	113.9	96.6	17.3	15.19	110.5	84.8	25.7	23.26
June 5	99.25	89.55	9.7	9.77	111.6	80.1	31.5	28.23
June 12	65.75	50.5	15.25	21.19	81.1	60.25	20.75	25.58

*The April plantings were not included in 1910.
†In 1912 the first two plantings in April were flooded out, due to clogging up of the drain tile.

THE CAUSE OF DECREASING POTATO YIELDS IN IOWA.

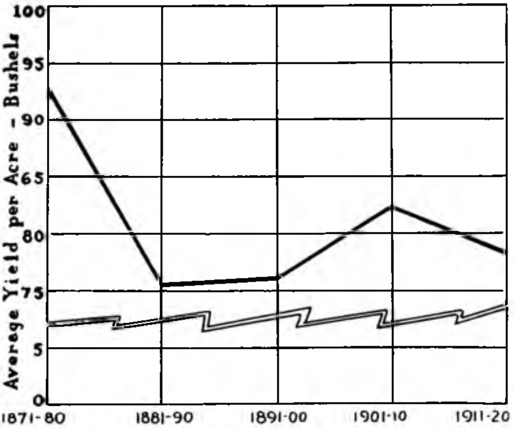

Fig. 3. Potato yields per acre by decades in Iowa.

Older growers repeatedly call attention to the fact that "potato yields are not what they used to be in Iowa," and raise the question as to the reason for this. Government crop reports show that yields have grown less, as indicated by the graph presented in fig. 3, giving the potato production in Iowa by decades for the past 50 years.

It will be noted that the yield per acre began to slump in the 70's, and that the loss was quite marked for the next decade. From 1901 to 1910 there was a decided gain in yield, approximately ten bushels per acre. In the decade from 1910 to 1920, production dropped seven bushels per acre, so that today it stands midway between the low point of 1900 and the high point of 1910.

As viewed from the standpoint of the market demands within this state, the situation has changed materially within the past decade. The production of potatoes per capita has decreased, as is shown in fig. 4. For the two decades from 1870 to 1890, the general trend of per capita production was upward, approximately six bushels in 1890. For the next two decades, 1890 to 1910, there was but little change in the production

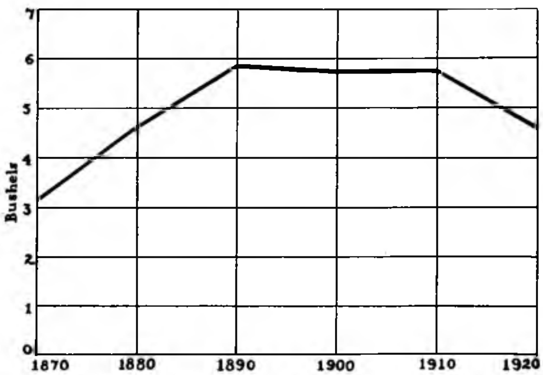

Fig. 4. Per capita production of potatoes in Iowa by decades.

per capita. In the decade from 1910 to 1920, there was a decline of approximately one bushel per capita.

It is the general practice of the growers in Iowa to plant early potatoes as soon as the ground can be gotten into condition. In the case of late potatoes, growers differ widely as to the best time for planting. Some plant the main-season crop at the same time they put in the early potatoes, while others, probably the majority, wait until after corn planting.

The minimum vegetative temperature for the germination of corn is given by Ewart* as 9° C. (48° F.). The air temperature on the average date of planting corn in central Iowa, as given by Director Reed of the Iowa Crop and Weather Bureau, is 55° F. The minimum vegetative temperature for the potato is 40° F. We then have a difference of 15° between the planting temperature commonly used for late potatoes and the effective temperature for this crop. It therefore seems evident that from the standpoint of temperature requirements the order of planting these two crops should be reversed. The present practice of planting potatoes after corn —in other words, late planting—is clearly one of the important reasons for the decline in potato production in Iowa.

The average yield per acre for the six-year period for the early planting, April 10, at Ames, was 138.7 bushels per acre. For the corresponding period, the yield for the state averaged 79.3 bushels, or a difference of 75 percent. In this case difference in time of planting was only one of the factors involved, but nevertheless, the results are suggestive.

. For the southern three-fourths of the state it is without doubt logical to give the potato crop secondary consideration, from the standpoint of profitable returns per farm operator.

But few crops are capable of equal development in all sections of the state. The problem of crop adjustment is one which grows out of experience and represents a stage thru which every agricultural region passes in its development. For the territory roughly described as the northern one-fourth of the state, the temperature conditions seem to be more favorable for potato production. Here potato production has made a much better showing in comparison with corn and other field crops, and in at least certain localities commercial potato production should have a permanent place, not to the exclusion of corn or any other crop, but in rotation with other crops, as under these conditions crop production is, in the long run, maintained at its highest level.

In Mitchell county, for example, according to the government† records covering the past 30 years, the average yield of corn per acre is 34 bushels and of potatoes 98 bushels, or,

*Pfeffer, Physiology of Plants, Vol. II, p. 76.
†Iowa Weather and Crop Service.

roughly, three bushels of potatoes to one of corn. The December 1 farm price for this same period is about the same for the two crops. In the case of the potato crop there are additional cost items for seed and for the labor of cutting and picking up. However, after making a full deduction for these items, including spraying, the potato crop has made a very creditable showing in comparison with other field crops.

The southern half of the state consumes potatoes far in excess of production. There is no good reason why the northern portion of the state should not produce at least a sufficient over-plus to supply the state. Northern Iowa has an excellent market at its door and a decided advantage in freight rates.

SOIL TEMPERATURE REQUIRED FOR SPROUTING OF POTATOES.

The early planting of potatoes depends primarily upon the temperature required for the sprouting of the seed piece and at what time in the spring the soil temperature, on the average, reaches this degree. But few accurately controlled experiments relative to the optimum and minimum temperatures at which the potato vegetates, have been made. Butler* reports that in a period covering 200 days at a temperature of 3.74° C. (38° F.), no growth was secured. This coincides with the studies made by Rappard** who found that "potatoes do not germinate in a soil whose lower border (minimum temperature) is 4° C. (38° F.) or less. Above this limit the sprouts develop more rapidly the higher the temperature of the soil."

The significant fact has been developed in the studies made by Smith† that while the date of planting early potatoes varies widely for different regions, the mean is practically the same at planting time and that this mean is 45° F.

Soil temperature readings have been made at the Iowa Agricultural Experiment Station for the past six years. These readings were at a uniform depth of seven inches. The maximum soil and air temperatures during the period of extreme heat show a difference of as much as ten degrees. A comparison of the mean soil and air temperature for the entire period shows an average difference of 2° F., the soil averaging that much lower than the air. The 45° F. air temperature reported by Smith as the one for planting early potatoes would therefore signify a soil temperature of approximately 43°.

At Ames the first planting, April 10, was commonly done when the soil temperature was near the 43° line and in this

*Butler—Journ. Am. Soc. Agron. **11:** 114-118, 1919.

Rappard. "Die chemish-physiologischen Vorgange Wahrend der Keimung der Kartoffel." Annalen der Landwirthschaft in d. k. Preuss. Staaten. **50: 293, Berlin 1867.

†U. S. Monthly Weather Bureau **43:** 222-236, May, 1915.

case we have the field results that, for early planting, the germination was reasonably prompt. The evidence therefore points to the conclusion that 40° F. is probably the lowest temperature at which the potato sprouts.

Accepting 40° F. as the minimum soil temperature for planting, the grower is in a position to determine better for himself the proper time for planting than by accepting certain arbitrary dates, which fail to take into consideration the peculiarities of the individual season. By acquainting himself with the time at which the seasonal rise in temperature normally crosses the 40° line, and comparing this with the general trend for the particular season, as to its being early or late, he has a fairly reliable index for his planting schedule.

In fig. 5 is given the 40° soil temperature in relation to the time in the spring at which the normal seasonal rise brings it up to this line, for Osage, Ames, and Keokuk. These three stations are given as representing the extreme range for the state. It will be noted that the 40° mark is crossed in a normal spring near the middle of April at Osage, April 10 at Ames and the last of March at Keokuk. This would signify a seasonal difference of two weeks between the extreme northern and southern portions of the state. It may also be noted that Keokuk is really in a tier of counties south of the Iowa line, which would modify the above statement somewhat.

In the above discussion consideration has been given to the temperature relation only. In practice, soil conditions would also govern. However, the two are inter-related, as a wet soil is usually cold, so that before the soil becomes warm it must first become dry.

Another angle to the problem is that of possible frost injury after the potatoes are up. The mean date for the last killing frost of spring for Osage is April 30, Ames, May 1, and Keokuk, April 13. The time required for potatoes to get above the ground varies somewhat from season to season. At this station it has averaged two weeks, which would place the last killing frost before the plants are up. In any case, spring frosts are less of a hazard to the potato crop than are those of autumn.

EARLY PLANTING AND AN EARLY MARKET.

The net returns per acre are often affected by the time of marketing, which, in turn, is determined by the time of planting. The Iowa grower occupies a unique position in regard to the market. The Kaw Valley of Kansas, the nearest competitor on the south, harvests in July and the forepart of August. The stock from this region is off the market in advance of the bulk of the Iowa crop. Minnesota stock, as will be noted by the

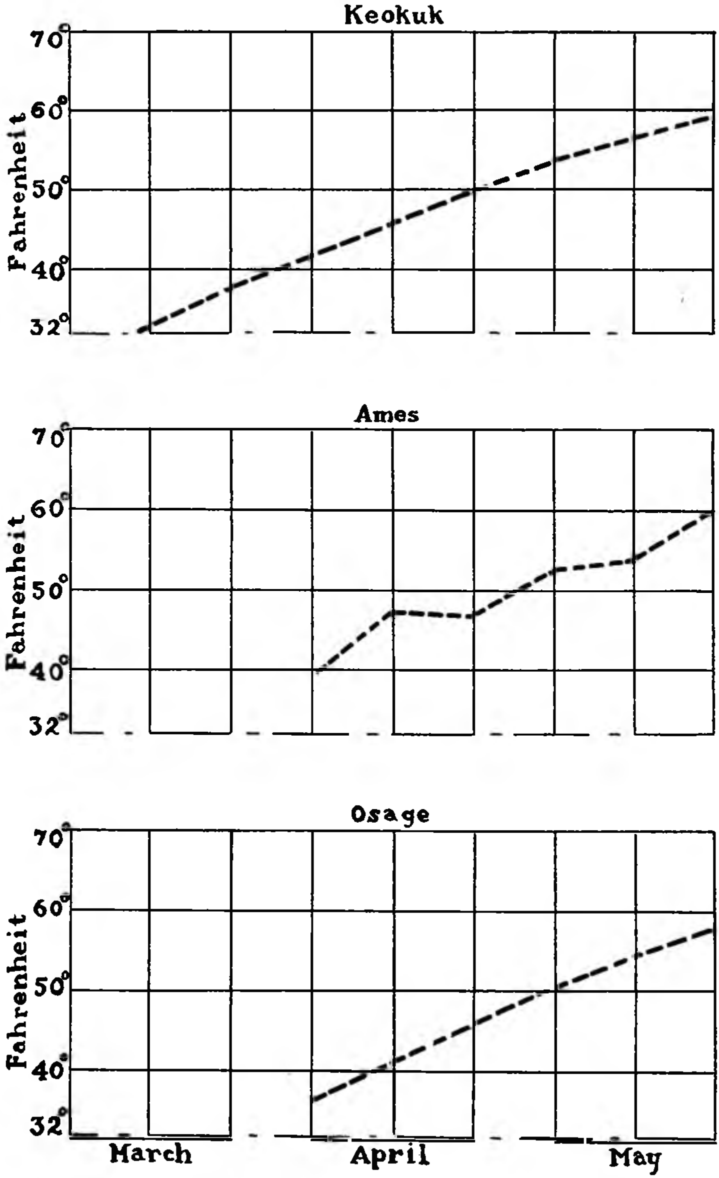

Fig. 5. Graph showing the seasonal rise of the soil temperatures and the average date at which the temperature crosses the 40° line, the minimum temperature for the sprouting of potatoes.

graph in fig. 6. does not come on the market in any considerable volume until a month later.

The figures in fig. 6 indicate that the Minnesota stock reaches its highest volume of shipments about the middle of October. Iowa, therefore, has the opportunity of filling in the interval and moving her crop between these two sources of supply and delivering to the September market. The Iowa grower who plants early can, in the majority of seasons, harvest for this market. By so doing he not only has the advantage of a keen market, but also of better prices, on the average. This feature of the market situation is clearly indicated by the graph* in fig. 7, showing the average range of prices for the United States by months for the past decade.

It will be noted that there is a substantial difference between September and October prices. At this time there is an important break in the market, due to the fact that in October the main-season crop for the potato belt is harvested and the markets are heavily loaded. It is therefore evident that, en-

*Prepared from statistical data given in the Market Reporter, U. S. D. Agr. 2:14, 218.

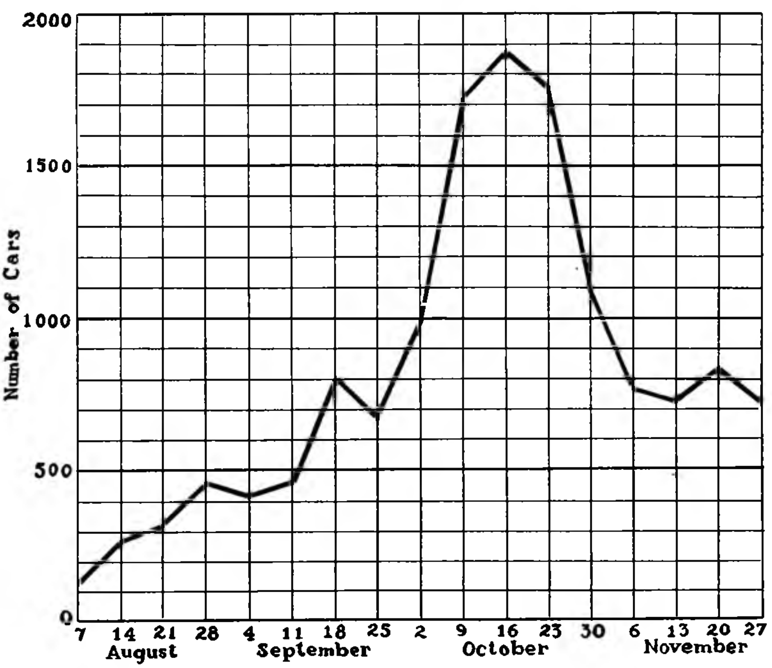

Fig. 6. Car-lot shipments of Minnesota potatoes by weeks for the year 1921.

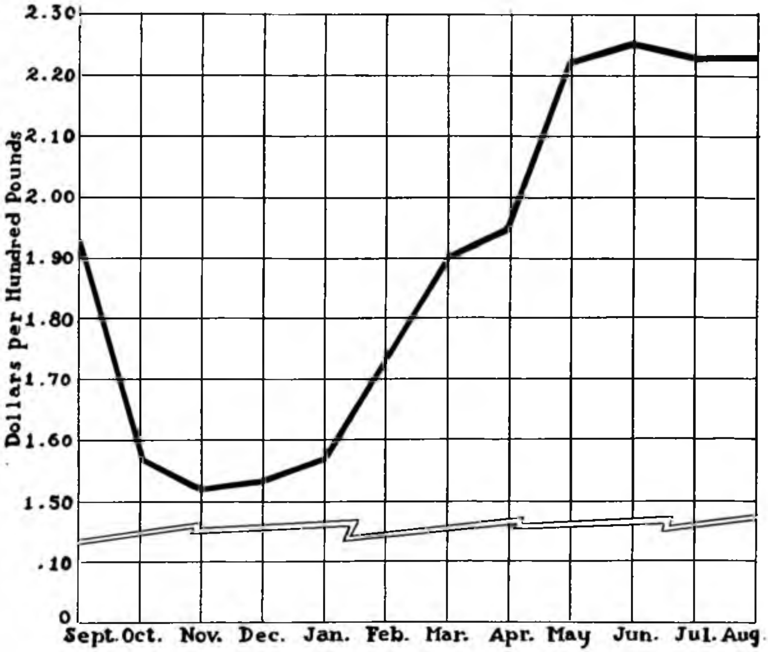

Fig. 7. Average prices per 100 pounds for potatoes on the first day of each month for the past ten years.

tirely aside from the matter of yield, there are important reasons for early planting in Iowa. Early planting and early marketing go hand in hand. A difference of a week or ten days at harvest time may represent the difference between returns covering only the actual cost of production and those showing a margin of profit.

FROST-INJURED POTATOES.

In some leading potato sections frost injury is one of the most serious hazards connected with the growing of the crop. On the one hand the market seriously objects to immature or skin-peeled stock, and on the other, delayed digging means frost risks. It is but seldom that the Iowa grower, who wisely plans his work, needs to find himself in this dilemma. In the case of early planting, the growing season, with rare exceptions, is sufficiently long to permit the crop to mature and be harvested before the severe frosts come on. Where late planting is practiced, especially in northern Iowa, the grower is likely to have either immature stock or more or less frost damage. In the latter instance the damage extends further than simply the loss of the few bushels which are directly affected. A badly chilled tuber soon becomes discolored, or "leaky." The adjoining tubers become wet and show thru the sack. Consequently the dealer may get an exaggerated idea of the extent of the damage, so as a matter of prudence the entire lot is seriously discounted. With the shift from late to early planting and early marketing which has recently come about in the northern section, frosted stock has practically disappeared.

The graph presented in fig. 8 indicates the range of dates for the first killing frost of autumn for northern Iowa. It will be noted that in seven of the fourteen years, or 50 percent of the time, killing frosts have occurred in northern Iowa the last week in September. The mean is October 6. The factor of safety, however, is indicated by the possible date of early occurrence rather than by the mean. It is therefore a matter of arranging the planting schedule in relation to the termination of growth the latter part of September for this territory.

The average date of the first killing frost of autumn for Ames is October 3, and for Keokuk the date is October 15. We thus have a range of two weeks between the extreme northern and southern portions of the state, the difference being greater between Ames and Keokuk than Osage and Ames.

The soil cools off more slowly than the atmosphere in the autumn. The occurrence of killing frosts, while establishing the limits for growth, does not necessitate immediate digging. However, nothing is gained by delaying harvest after killing frosts, and there are added hazards. Partly exposed tubers are likely to be damaged and it is difficult, if not impossible, to cull out the injured tubers until some days after harvesting. A rainy spell may set in, leaving the soil in bad shape for harvesting, yet the work must proceed whether or no. Muddy stock is always severely discounted on the market. There are therefore important advantages in favor of prompt harvesting following killing frosts, if the soil is in proper condition.

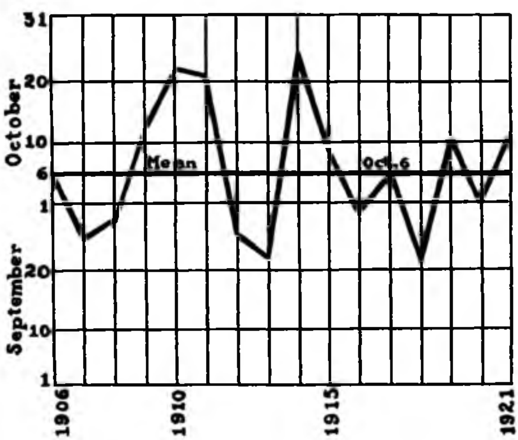

Fig. 8. Range of first killing frost in the fall at Osage, Iowa.

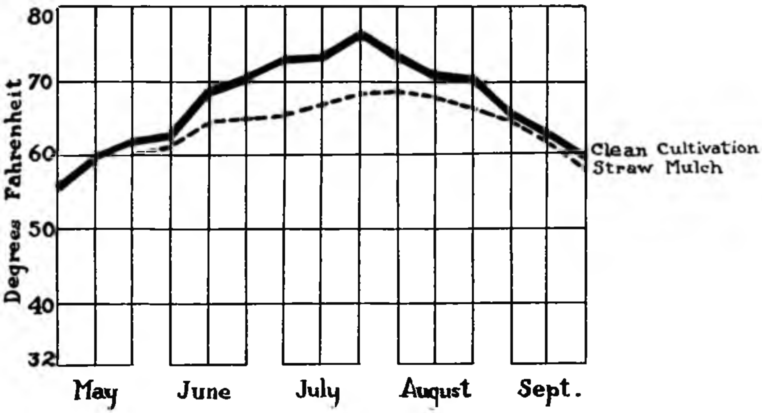

Fig. 9. Range of soil temperature, under clean cultivation and a straw mulch, for the growing season.

STRAW MULCHING OF POTATOES.

The straw mulch, which is used occasionally by growers for the purpose of eliminating cultivation, is the most practicable method of lowering the soil temperature under Iowa conditions.

To determine the exact influence of such a mulch upon the soil temperature and the consequent effect upon the yield, the following experiment was undertaken: Plot 1, the check, was given clean cultivation. Plot 2, which was planted at the same time and with the same stock, was given a mulching of straw of a sufficient thickness to be six inches deep when it had settled. This was applied as soon as the potatoes were completely up.

Fig. 9 shows the comparative soil temperature under clean cultivation and under a straw mulch at a depth of seven inches. The records indicate that a straw mulch has a marked influence upon the temperature of the soil. This is particularly the case for the month of July and the first half of August. The mean for the past six years shows a difference of 4°, tho in a number of instances the difference was much greater than this. The heat wave reaches its highest point, on the average, in the third week of July. Fig. 10 shows the comparative temperature readings under a straw mulch and clean cultivation for the last half of July, 1916. The extremes are as much as 20°. The straw mulch temperature is therefore not only decidedly lower, but also more uniform.

EFFECT OF MULCH ON YIELD.

Table III shows the effect of a mulch on yield. The percentage of culls is greater for the clean cultivation and after deducting for culls, the net yield of marketable stock is decidedly greater for the straw mulch, the average difference being 27.5 bushels or 28 percent. Emer-

TABLE III. STRAW MULCH VS. CLEAN CULTIVATION.
Average for Three Years, 1916-17-18, Ames.

Plot	Total Yield bushel per acre	Culls bushel per acre	Per cent of culls	Marketable yield bushel per acre
Mulch	111.6	14.8	12.49	96.8
Clean	90.2	20.9	21.32	69.3

son* reports an average increase of 25 percent in yield of marketable tubers in eastern Nebraska under straw mulch.

There is also a difference in the grade which is not indicated in table III. The general average as to size, uniformity and freedom from second growths is very much in favor of the mulched plot. This is particularly the case in dry seasons, due to the conservation of moisture.

There is commonly a supply of straw available for mulching purposes and the plan of spreading it on the ground instead of burning, as commonly done, is certainly to be recommended as an agricultural practice. The humus derived therefrom contributes in an important way towards improving the friability of the soil, increases its water holding capacity and provides a favorable environment for the growth of the soil bacteria.

There are certain possible objections to the straw-mulch method. As commonly applied it involves considerable hand labor in spreading. Straw spreaders are now being offered on the market and it is possible that hand labor may be largely eliminated.

The harvesting of straw-mulched potatoes presents certain obstacles. It is difficult to use the digger unless the greater portion of the straw is first removed. If this has to be done following heavy rains, the straw is inclined to mat down and is heavy to handle. The potatoes form nearer the surface than with clean cultivation, but the potatoes commonly run so much larger that it is necessary to dig to about the usual depth, anyway.

A straw mulch also affords a possible fire hazard, particularly if the field adjoins the farmstead area.

In brief, the use of a straw mulch seems to have certain points in its favor from the standpoint of increased yields and a better grade of potatoes. The labor saved in cultivating is probably counterbalanced in harvesting. On the whole the plan has its limitations as a commercial proposition, but may prove advantageous for small patches.

*Neb. Agr. Exp. Sta. Bul. 146:36.

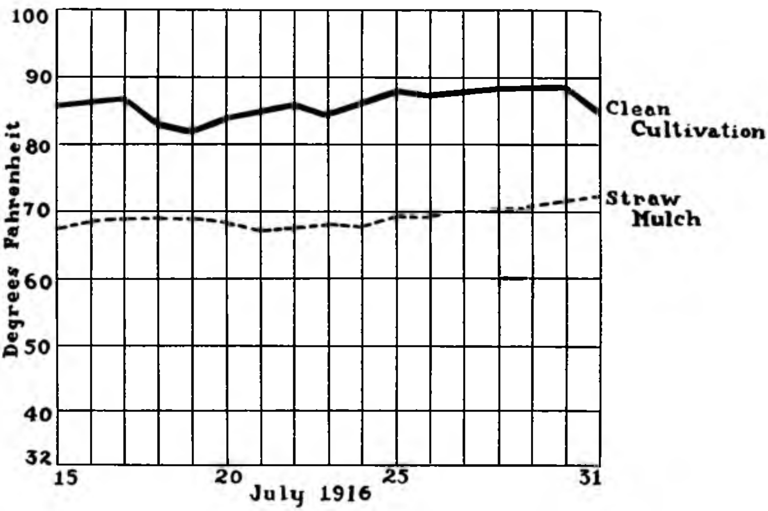

Fig. 10. Comparative soil temperatures under a straw mulch and clean cultivation during the period of extreme heat.